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THE GRANARY WEEVIL[1]

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INTRODUCTION

The granary weevil (*Sitophilus granarius* L.) (fig. 1) is well named, for of all the primary grain pests it is par excellence a pest in the granary or storehouse. Unlike its more successful and widespread rival, the rice weevil (*Sitophilus oryza* L.), the granary weevil possesses only rudimentary wings and does not appear to thrive in tropical and semitropical climates. Restricted as it is to the granaries of the colder climates, it seems to be finding it increasingly difficult to withstand the combined effect of limited numbers of generations due to cold and the modern methods of handling and protecting grain.

As late as the decade from 1860 to 1870 the granary weevil was the prevailing species of weevil in grain throughout the northern portion of the United States. E. A. Schwarz, of the Bureau of Entomology, states that *Sitophilus granarius* was the only grain weevil present among the insects collected by C. V. Riley in Missouri and later acquired by the United States National Museum. The writers, who have examined many samples of grain from various grain centers of this country, believe that the granary weevil is a minor pest as compared with the rice weevil, and that it is responsible for a relatively small amount of the damage caused by calandrid pests in this country, notwithstanding the numerous instances of serious injury that are constantly coming to one's attention. Keys distinguishing the larvae and adults of *granarius* and *oryza* have been given by Cotton (*13*).[2]

SYNONYMY

The granary weevil was described and named by Linné (*44, p. 378*) in 1758 as *Curculio granarius*. Numerous references to this weevil

[1] The biological data contained in this bulletin are based on work conducted in Florida from 1919 to 1921 and in Washington, D. C., from 1921 to 1923.

[2] Reference is made by number (italic) to "Literature cited," p. 32.

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appeared in literature before this time. It was described in 1710 by Ray (*55*) under the name of Scarabaeus and again by Linné (*43*) in 1746 under the name of Curculio. In 1798 Clairville and Schellenberg (*59, p. 62*) erected the genus Calendra for the species *granaria* and *abbreviata*. Latreille (*41, p. 431*) in 1810 designated *abbreviata* Fab. as the type of the genus Calandra (*sic*), and in 1838 Schoenherr (*60, p. 967*) erected the genus Sitophilus to include the species *granarius* and *oryzae*. Hence, as noted by Pierce (*51, p. 26*) in 1919, the correct generic name for the granary weevil is undoubtedly Sitophilus and not Calendra or Calandra. The synonyms of the species are as follows:

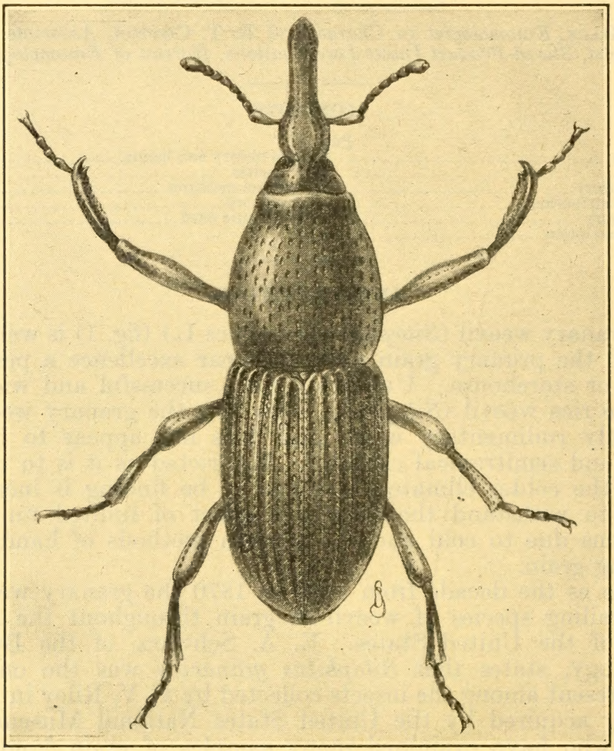

FIG. 1.—The granary weevil (*Sitophilus granarius*): Adult, dorsal view. Enlarged about 38 times

Sitophilus granarius Linné

Curculio granarius Linné, Syst. Nat., ed. 10, p. 378, 1758.
Curculio segetis Linné, Syst. Nat., ed. 10, p. 381, 1758.
Rhynchophorus granarius Herbst, Jablonsk. Natursystem., vol. 6, p. 14, Pl. 60, fig. 7, 1795.
Curculio policarius Voet, Col., ed. Panz., vol. 4, p. 54, Pl. 37, fig. 17, 1798.
Calendra granaria Clairville and Schellenberg, Helv. Ent., vol. 1, p. 62, 1798.
Curculio unicolor Marsham, Ent. Brit., p. 275, 1802.
Rhynchaenus segetis Latr., Hist. Nat., xi, 193, 1804.
Cordyle granarius Thunberg, Nova Acta Ups., vol. 7, p. 112, 1815.
Calandra frumentarius Stephens, Cat. Brit. Ins., pt. 1, p. 148, 1829.
Sitophilus granarius Schoenherr, Gen. Curc., vol. 4, p. 977, 1838.
Sitophilus remotepunctatus Gyll., Schh., Gen. Curc., vol. 4, p. 979, 1838.

ECONOMIC HISTORY

The granary weevil was well known as a pest in stored grain long before its description by Linné (*44*) in 1758, and numerous references to it are found in the publications of earlier writers. Remains of this weevil are said (*23*) to have been found in a vial in an ancient Gallo-Roman cemetery and also in a Marovingian tomb. Plautus (*52, pp. 251–252*), writing about 196 B. C., speaks of a curculio in stored grain which was presumably this species, and there seems to be little doubt that the *curculio* of Pliny and the Romans was this weevil. Von Schwenckfeld (*61, p. 527*) in 1603, Rango (*54*) in 1665, Commodus (*10*) in 1668, and Van Leeuwenhoek (*42*) in 1695 all referred to this weevil in their writings. Redi (*56*) published a figure of it in 1668. Since its description by Linné, innumerable accounts of the weevil have appeared.

The writers have over 300 references to the granary weevil. Naturally many merely pass on information previously published; surprisingly few contain real contributions to our knowledge. Only one paper, that by Strachov-Koltchin (*65*), contains a decided contribution to our knowledge of the various stages of the life cycle, as viewed from a modern standpoint. Although the work of this Russian was published in 1915, a translation [3] was not available for the writers until 1923; hence, the data hereinafter presented were secured uninfluenced by those of the work in Russia. Only a few of the more important papers, from an American standpoint, can be mentioned.

Duhamel du Monceau (*24*) published a short account of the granary weevil in 1761 and gave directions for combating the weevils and preserving the grain. In 1775 De Geer (*31, pp. 239–240*) stated that the weevils were commonly known as calandres. The same common name was used by Van Leeuwenhoek about a hundred years before, so it is probably of rather ancient origin. In 1790 Olivier (*48, pp. 442–444*) published a lengthy account that has served as a basis for a majority of the articles on the granary weevil up to recent times. He described the weevil and its habits and reported numerous experiments for its control. He came to the conclusion (amusing in these days) that fumigations only resulted in imparting a bad odor to the grain without seriously inconveniencing the weevils. He found that a temperature of from 167° to 190° F. would kill all stages of the insect but had a tendency to damage the wheat. He observed that when a pile of infested wheat was stirred up, the weevils crawled away in their endeavors to escape, and this suggested to him the following method for destroying them: "In the early spring before any eggs have been laid, several small piles of wheat should be formed near the large pile. The large pile should then be stirred and the weevils will leave the large pile and on encountering the small piles will enter them to seek shelter. The small piles should then be treated with boiling water to kill the weevils."

Latreille (*40, pp. 54–56*), in 1804, gave an extended account of the weevil, noting, among other things, that the period from egg to adult was about 40 days, and that one pair of weevils were capable of having 6,045 descendants in a single season. He also noted that

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[3] A translation of this article by Strachov-Koltchin is on file in the Library of the Bureau of Entomology, United States Department of Agriculture

the weevils were very resistant to cold. Mills (*46*), in 1836, advocated the use of heat to kill the weevils, finding that a temperature of 130° to 140° F. would kill all stages without injuring the grain. He recommended using a room heated with hot-water pipes in which to treat infested grain. Gavit (*30*), in 1849, published a good account of the weevil, stating that the life cycle lasted from 40 to 45 days and that the adults lived for 1½ years or more.

Curtis (*14, pp. 323–328*), in 1860, published an interesting account of the insect in England, and Taschenberg (*68, pp. 63–65*), in 1865, gave a good account of the species in Germany. The latter author noted that badly weeviled wheat had a high temperature and stated that one female weevil was supposed to lay as many as 150 eggs. Taschenberg's observations in Germany have more recently been interestingly added to by Zacher (*71, 72*) and Teichmann and Andres (*69*). In 1869 Walsh and C. V. Riley (*70*) noted the vesicatory properties of the granary weevil. These properties were disproved in 1922 by W. A. Riley (*57*) and Defiel (*17*). In 1879 Ormerod (*49, 50*) wrote short articles on the granary and rice weevils and suggested trapping the beetles in vessels of water, and this idea was further developed by Dendy (*18*) in 1918. Kompfe (*39*), in 1879, recorded breeding the weevil from egg to adult in four weeks. Cotes (*12*), in 1888, while not discussing *granarius* as one of the grain pests of India, gives an interesting bibliography of grain weevils. Decaux (*16*), in 1890, published a few notes on the life history of the weevil and recorded rearing several species of chalcid parasites from it. Chittenden (*6, 7, 8*), in 1895 and 1896, published short accounts of the habits and depredations of this insect in North America.

Cole (*9*), in 1906, found that a fairly moist, ventilated atmosphere of about 80° F. was most satisfactory for the development of the granary weevil; that at 51° to 76° F. weevils were still alive after 48 days when kept in a moist atmosphere with food, but that when kept in a dry atmosphere they were dead by the end of the fourteenth day.

In 1915 Strachov-Koltchin (*65*) published an excellent account of the life history and habits of the granary weevil in Russia. He found that the length of the larval period is from 21½ to 84 days, according to the prevailing temperature, and that the length of the pupal stage is from 10 to 22 days. He gives data on oviposition based on adults reared from eggs laid in grain by females of unknown ages.

Dendy and Elkington (*19, 20, 21*), in a series of reports appearing in 1918 and 1920, discussed the effect of air-tight storage on the granary weevil and the vitality and rate of multiplication of this weevil.

Back and Cotton (*2, p. 5*), in 1922, stated that adult weevils may live for 10 months or more, and that in this period each female may lay from 200 to 300 eggs, these statements being summarized from actual data bearing upon the subject.

Chapman (*5*), writing in 1923, records experiments indicating that no stage of the granary weevil survives the process of milling semolina and that adults will not oviposit in semolina, with the natural result that macaroni is not infested as it comes from the press even though it is made from wheat badly infested.

A key to the principal insect pests of grain, including the granary weevil, was published by Zverezomb-Zubovski (*73*) in 1923, and is especially interesting because of the 78 illustrations, the keys, and the Russian bibliography of 72 entries dealing with grain pests. A translation of this paper is on file in the Library of the Bureau of Entomology, United States Department of Agriculture. Entomologists are directed to this paper in any study of the Russian literature.

ORIGIN AND DISTRIBUTION

The origin of the granary weevil is not definitely known, although it has been thought to have originated either in Asia or in the region bordering the Mediterranean Sea. Unlike the other members of the genus Sitophilus, which thrive best in a tropical or subtropical climate, the granary weevil is now distinctly a temperate-climate species.

Because of its habit of breeding in grains of all kinds, it has been carried by commerce to all parts of the civilized world. It does not thrive in warm climates, even though it is occasionally found there in apparently thrifty cultures. In tropical and subtropical climates it soon dies out. This seems true in spite of the fact that one of the best cultures seen by the writers came from Texas in chick-peas from Northern Mexico. Cotes (*12*) in 1888, Fletcher (*27*) in 1911, and Fletcher and Ghosh (*28*) in 1920, in their articles dealing with grain pests in India, do not mention *granarius* as a grain pest along with *oryza* and others.

In colonial days, the granary weevil appears to have been abundant and widespread over the United States and much more common than the rice weevil, *Sitophilus oryza.* Possibly there existed a confusion in the identification of these closely related weevils. At the present time, the granary weevil is common in all the northern States and is the predominating form in the States of the extreme north. It is not often found breeding farther south than North Carolina.

Cooley (*11, p. 127*), in 1914, in recording the presence of *granarius* in Montana, intimates that the species was not commonly found there, for he says, "The knowledge of its presence in Montana should put grain growers on their guard." Chapman (*4, p. 38*), in 1921, writes, "It is far more common in the south than in Minnesota. Its importance in the north is due to the fact that it is continually shipped in with southern wheat."

Swenk (*66, p. 366*), of Nebraska, in writing of the principal insects injurious to agriculture during 1908–9, says: "A really tremendous amount of grain is lost every year in Nebraska through the attack of stored-grain pests after the grain has been stored in the granary. Of course the insect most concerned in this destruction is the common grain weevil (*Calandra granaria*)." In 1922 Swenk (*67, pp. 3–4*) again states that the granary weevil is common throughout Nebraska, but refers to the presence also in southern Nebraska of *S. oryza.* Dean (*15, p. 198*), in 1913, lists the granary weevil along with the rice weevil and the Angoumois grain moth as the three principal pests in Kansas of whole grains. Girault (*32, p. 70*), in 1912, in discussing the granary weevil, says, "The species is widely distributed in the United States but is more common southward." Stedman

(*63, pp. 139–141*), of Missouri, in 1902, mentions *granarius* as the only true weevil in Missouri, while in 1915 Haseman (*36, p. 35*) of the same State records the granary weevil, and not the rice weevil, among the stored-grain pests of Missouri. On the Pacific coast the granary weevil is reported in 1915 by Essig (*26, pp. 305–307*) as very common throughout the State of California.

In the typically southern States, however, especially those bordering on the Gulf of Mexico, where weevil damage is greatest, the injury is caused not by the granary weevil but by the rice weevil. Quaintance (*53, p. 366*), in 1896, writes from Florida that "the granary weevil is not sufficiently abundant to be the cause of much damage," the rice weevil and the Angoumois grain moth being responsible for the greater part of the injury done to stored grain. Hinds (*38*), in 1914, in discussing the pests of stored corn in Alabama, does not mention the granary weevil. Smith (*63, p. 10*), in 1909, writing from North Carolina, states that the granary weevil "requires only passing mention here, for the rice weevil far surpasses it in numbers and destructiveness in the Southern States," and Sherman (*62*), in 1903, also of North Carolina, does not mention *granarius* in writing of common pests of grain. Back (*1*), in 1919, in discussing the conservation of corn from weevil attack in the Gulf Coast States, after an extended study of the stored-grain situation, did not consider *granarius* sufficiently important in that region to be mentioned.

It is accepted, naturally, that trade carries the rice weevil well into the territory of the granary weevil, particularly at the large ports such as New York and London (see reports of Durrant (*25*) in 1921), receiving cargoes of grain from warm climates. Riley and Howard (*58*), in 1888, reviewing a paper by R. A. Philippi on the changes in the fauna of Chile, caused by man, state that the two grain weevils occur, and that the damage done by *granarius* is often enormous. Doane (*22, p. 312*), in 1919, records the presence of *granarius* in Australian wheat brought into the United States through Pacific ports, but found that *oryza* was the more abundant. The writers, in examining Australian wheat brought into this country at Baltimore during the war period, found that it contained relatively few *granarius* as compared with *oryza*. Gurney (*35, p. 41*), in 1918, in discussing the insect pests of New South Wales, states that, while *oryza* was very abundant, *granarius* had been noticed twice only in imported grain. Froggatt (*29, p. 485*), in 1903, writes that *granarius* is a comparatively rare beetle: "I have met with it for the first time for over a year in a packet of macaroni left at the office, which was purchased at a Sydney grocer's." In South Africa, *oryza* and not *granarius* is the destructive species. Lounsbury (*45, p. 94*), writes in 1903, "The rice weevil is by far the more abundant species at the cape." The statement by Herrick (*37, p. 259*), in 1914, that *granarius* "is a more cosmopolitan species" than *oryza*, does not seem true to the writers, especially in these days (1923).

Since the granary weevil has no effective wings and is by nature not very active, it is found chiefly in granaries and other storehouses and has become now dependent upon man for its dissemination or spread. It seems very possible that, with the present-day tendency to treat all infested grain and to ship only clean grain, the granary weevil will become more and more scarce and may even be eliminated as a serious pest of stored grain in any part of America.

NATURE OF INJURY

The granary weevil is destructive to grain (figs. 2 to 4) and grain products (fig. 5) in both its adult and larval forms. The adults feed throughout their long lives and may occasion as much injury as their larvæ. The adults will feed upon many seeds and manufactured cereal products and are found in flour. They do not oviposit in any loose and finely divided grain particles too small to serve as food for the development of a single larva. Thus flour and similar materials, like semolina used in the manufacture of macaroni, may be fed upon by the adult weevil but not by the larvæ unless the substances become caked by long standing, in which case they are used by the adult weevils as suitable materials for the rearing of their young.

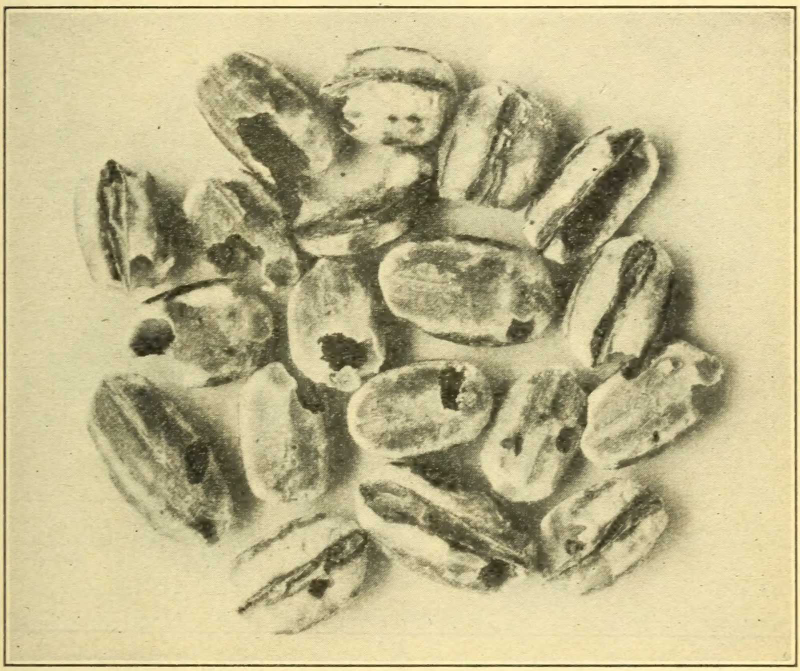

FIG. 2.—Injury to pearled barley resulting from development of larvæ and feeding of adult beetles of the granary weevil in making exit from kernels

Ordinarily when adult weevils are found crawling over sacks of flour and similar finely divided grain products they are migrating from near-by infested grain in the berry, and their presence will not cause injury except that uninformed buyers, on noting the presence of the weevils, may refuse to purchase or may insist on a lower price. The writers have known of instances where flour-mill owners have incurred considerable expense to hand-pick granary weevils from sacks of freshly manufactured flour standing overnight in the mill.

The adult weevil may become established and cause loss in cartoned grains like pearled barley (fig. 2). In an instance recently called to the attention of the writers a considerable shipment of pearled barley in small cardboard cartons was found to be infested with the granary

weevil. The adults were not only causing a general infestation of the grain, but were opening the cartons to the attack of other grain pests by boring small holes in their efforts to escape, similar to those made in pill boxes and shown in Figure 6. The entire shipment was condemned.

Injury by the larvæ consists in the destruction, by feeding, of a larger or smaller part of the kernel, and in the fouling of the seed by their excrement. The development of one granary weevil larva will reduce the weight of a wheat kernel over 50 per cent and the adult before leaving the kernel may destroy even more. The destruction caused in all grains depends largely upon the abundance of the larvæ.

FIG. 3.—Wheat kernels damaged not only by development of larvæ but by continued feeding of adult beetles of the granary weevil. These kernels are reduced to mere skeletons and can be crushed flat as paper by the least pressure

Horses and other stock have been reported at times injured by being fed weeviled grain or other grain products filled with the feces and other débris left in the grains when these are infested. Recent investigation by Riley (*57*) and Defiel (*17*) show that the granary weevil has no poisonous qualities. The writers have seen very badly weeviled grain fed to animals without bad results and have yet to establish a clear instance in which injury to animals was caused by weevils.

Badly infested seeds, particularly wheat (fig. 3) are rendered worthless for seeding.

The destructive possibilities of the granary weevil were clearly shown during the World War when immense quantities of wheat were stored in Australia, a considerable quantity of it, owing to a lack of shipping, being held in storage for several years. This wheat became

infested with weevils and only prompt treatment prevented very severe losses. Hundreds of thousands of tons of wheat were sterilized and screened and from every 2,500 bags of wheat so treated between 200 and 300 pounds of weevils were removed, an enormous number when one considers that there are about 442,000 weevils to the pound. Although three species of weevils predominated in this wheat, the granary weevil is said to have caused the most damage.

FIG. 4.—Corn kernels showing evidences of injury by the granary weevil. Note long white streaks on kernels to right. These indicate burrows of very young larvæ of the weevil just beneath surface of grain

TECHNICAL DESCRIPTION

THE BEETLE

(Fig. 1)

Elongate-oblong, feebly convex. Chestnut brown to piceous, moderately shining. Beak two-thirds as long as thorax, slender, cylindrical, finely and sparsely punctate. Thorax sparsely punctate, punctures coarse and on the disk more or less fusiform. Elytra deeply striate, striæ punctured at bottom, not serrate; intervals smooth, alternately wider and more elevated, especially toward the base; the sutural with a row of elongate punctures. Pygidium coarsely cribrate. Body beneath coarsely and less densely punctured than in *oryza.* Length 3 to 4 mm.

The original description of Linné follows:

"C. longirostris piceus oblongus, thorace punctate longitudine elytrorum."

THE EGG

(Fig. 7, *e*)

Egg opaque, shining, white, ovoid to pear-shaped in form, widest below middle, bottom broadly rounded, neck narrowing gradually toward top, which is somewhat flattened and bearing a small rounded protuberance that fits into a cap or plug cementing the egg in place.

Length 0.68 to 0.80 mm., width about 0.33 mm.

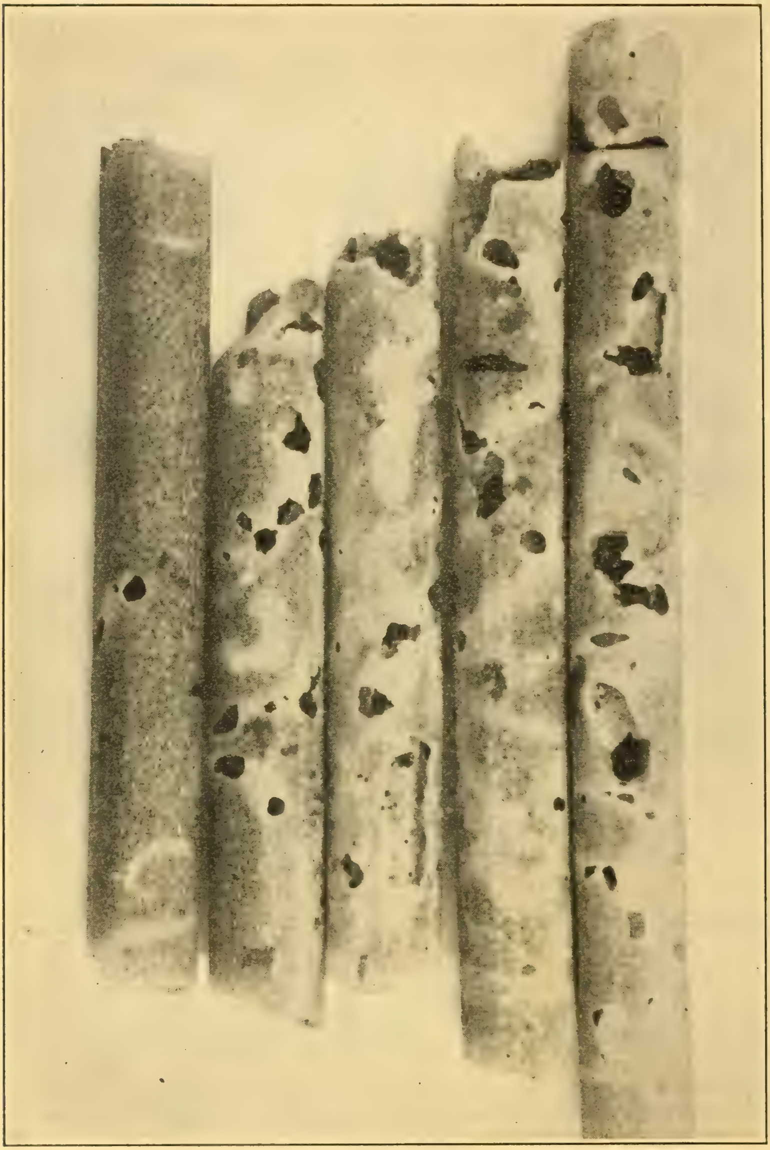

FIG. 5.—Injury to macaroni by the granary weevil. Macaroni is sometimes reduced to a powder by continued feeding of the weevil. The opaque whitened areas indicate progress of developing larvæ; the openings in the macaroni are caused by feeding of adult weevils

THE LARVA

(Fig. 7, *a* to *d*, *g* to *j*)

Mature larva (*f*) 2.5 to 2.75 mm. in length. A pearly white, fleshy grub, very thick bodied, the ventral outline being approximately straight, whereas the dorsal outline is almost semicircular. Ten abdominal segments; ninth small, tenth reduced, eighth and ninth forming a sort of pygidial plate.

Head (*b*) light brown in color, the anterior margin and mandibles much darker. Head longer than broad and somewhat wedge shaped, the sides broadly rounded from middle to apex, which is slightly angular. Sides nearly straight from middle to the anterior angles, and lateral area with an oblique, longitudinal, lighter stripe or area.

Epicranial and frontal sutures distinct and light in color; also two oblique, longitudinal, light stripes rising from frontal sutures and coalescing with epicranial suture near base of head.

Frons subtriangular, with a distinct, dark, median line indicating the carina running from the posterior angle to beyond the middle. Sutural margins irregular or sinuate. Frons provided with five pairs of large setæ, the sutural margins each bearing a large seta.

FIG. 6.—View of pill box, 1¼ inches in diameter, showing three exit holes bored by adults of the granary weevil in escaping from box. Cereal cartons may be thus opened to the attack of cereal pests

Clypeus attached in front of frons and broadly transverse, broad at base, sides narrowing toward the apical angles, slightly longer and broader than labrum, and bearing on epistomal margin two fine setæ on each side.

Labrum (*c*) distinctly broader than long, with two small lateral and a larger, rounded, median lobe. Labrum provided with six large dorsal setæ and two sensory spots, two marginal, short, thickened setæ on each lateral lobe, and six similar marginal setæ on median lobe.

Each epicranial lobe bearing the following setæ: One close to posterior angle of frons and located within the oblique, longitudinal stripe rising from the frontal suture; one very small seta posterior to this and near occiput; two anterior to it on disk of epicranium; two opposite middle of frons; one opposite middle of mandible; one opposite hypostomal angle of mandible; and one on hypostoma near base of mandible.

Eye represented by a single ocellus.

Antenna a fleshy two-jointed appendage located at the lateral angle of the frons, first joint broad and short, second slender and short.

Mandibles (*d*) stout, triangular, with the apex produced into a broad apical tooth; inner edge toward the apex provided with a subapical tooth and a small medial tooth; no molar part. Dorsal area of mandible provided with two stout setæ set apart.

Maxilla with cardo present and distinct. Maxillary mala (*g*, *h*) entire, tip obtuse, dorsal and ventral surfaces smooth, lightly chitinized, dorsal surface with a longitudinal row of six plain stout setæ, tip with two short and two longer setæ. Maxillary palp extending slightly beyond mala, two-jointed, proximal joint thick and rounded, bearing a single seta near apex; distal joint fingerlike, bearing several terminal papillæ. There are three other setæ on maxilla, two located on the vaginant membrane between palpus and palpifer and one, stouter and longer, midway between palpus and cardo.

Mentum, submentum, and maxillary articulating area fused into a fleshy region bearing three pairs of stout setæ. Eulabium posteriorly enforced by a median triangularly bent chitinization. Between the palpi a small slightly

bilobed ligula. Labial palp short, conical, two-jointed, distal joint of palp with several small, fleshy, terminal papillæ. Eulabium bearing two setæ on ventral surface; ligula bearing four small setæ and two sensory spots on ventral side and one pair of setæ on dorsal side.

Paragnathal region or maxillular region with a median fleshy area and two setose lateral lobes.

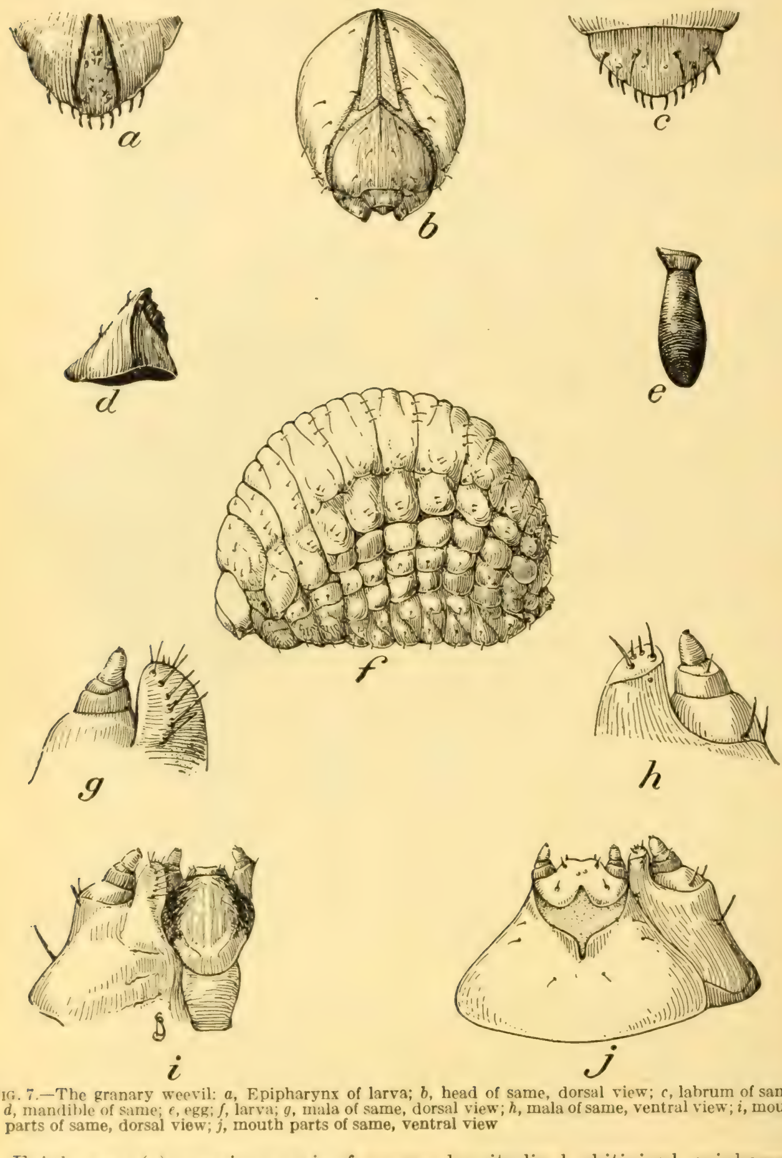

FIG. 7.—The granary weevil: *a*, Epipharynx of larva; *b*, head of same, dorsal view; *c*, labrum of same; *d*, mandible of same; *e*, egg; *f*, larva; *g*, mala of same, dorsal view; *h*, mala of same, ventral view; *i*, mouth parts of same, dorsal view; *j*, mouth parts of same, ventral view

Epipharynx (*a*) carrying a pair of narrow, longitudinal, chitinized, epipharyngeal rods approaching each other posteriorly. Between these there are usually 12 small setæ somewhat asymmetrically arranged, as follows: Two near anterior margin of epipharynx, a median group of four much smaller ones posterior to these, a pair of larger ones posterior to the group of four, and finally another median group of four very small setæ posterior to these.

Prothorax dorsally not divided, but two areas, præscutal and scuto-scutellar, are roughly indicated by rows of setæ. Præscutal area with six pairs of setæ, the last two of which occur on the alar lobe, scutoscutellar area with four pairs of setæ. The thoracic spiracle is located on a lobe pushed into the prothorax from the epipleurum of the mesothorax. It is bifore, elongate, larger than abdominal spiracles, and placed with the fingerlike air tubes pointing dorsad.

The mesothoracic and metathoracic segments are divided above into two distinct areas, a spindle-shaped præscutum provided with two pairs of minute setæ, and the scuto-scutellum and alar area. The scuto-scutellum has eight pairs of setæ and two pairs of hairs on each alar lobe. The epiplerum of the mesothorax and metathorax bears a pair of setæ. The sternum of the thorax consists of a median area or eusternum and two lateral lobes more or less connected medianly behind the sternum. The median portion is the sternellum and the lateral portions are the parasternal plates. Each thoracic sternum bears a pair of hairs, each coxal lobe of prothorax bears three pairs of hairs, and each coxal lobe of mesothorax and metathorax bears five hairs.

Each tergum of first four abdominal segments divided above into three distinct areas, præscutum, scutum, and scutellum. Each tergum of fifth to seventh abdominal segments divided above into only two areas, the first containing præscutal and scutal elements, the second representing the scutellum. Below these two areas and adjacent to the epipleurum is the alar area. Below a very indistinct and abrupt dorsolateral suture and above a well-defined ventrolateral suture is a large, not subdivided epipleurum. The abdominal epipleura are located considerably higher than the thoracic lobes. Below the ventrolateral suture is the hypopleurum, subdivided into three lobes, one directly below another. Below the hypopleurum is the coxal lobe and below that the sternum consisting of the eusternum and a posterior triangular area representing the parasternum or the parasternum fused with the sternellum. Abdominal segments provided with setæ, as follows: Each præscutum bears a pair of setæ; each scutellum bears three lateral setæ; each alar area bears a pair of setæ, and each epipleural lobe bears a pair of setæ. The second part of each hypopleural lobe bears a seta, each coxal lobe bears a seta, and there is a pair on the eusternum.

Eighth abdominal segment smaller than the typical segment; tergum declivous and without distinct tergal areas; ninth segment rather small; tenth ventral and very small. Abdominal spiracles placed anteriorly and in a small separate corner piece, probably of the alar area; spiracles bifore and found on abdominal segments 1 to 8, that on the eighth being located slightly more dorsad than the rest.

Measurements of larval stages

Stage	Width of larval head
	Mm.
1	0. 25 to 0. 26
2	. 36 to . 37
3	. 47 to . 48
4	. 61 to . 65

THE PUPA

Pupa (fig. 8) uniformly white when first formed; length 3.75 to 4.25 mm., width 1.75 mm. Tips of elytra attaining fifth abdominal segment, inner wings rudimentary and almost completely concealed by elytra. Tips of metathoracic tarsi extending beyond tips of elytra. Head rounded, beak elongate. Head with two prominent spines toward vertex, a group of two small spines and two spinules on each side above eyes, two pairs of small spines near anterior margin and one on each side of front between eyes, three pairs of spines on beak between frontal ones and base of antennæ, a pair of small ones on beak midway between base of antennæ and tip of beak, a pair on sides of beak between latter pair and tip of beak, and two pairs of minute spines on tip of beak. Prothorax provided with one pair of anteromarginal setigerous tubercles, one pair of anterolateral, two pairs of mediolateral, and four pairs of dorsal setigerous tubercles; also a pair of minute mediolateral ventral spines. Mesonotum and metanotum normally each provided with three pairs of spines; one or more pairs often missing. Abdomen with seven distinct dorsal tergites, the seventh being much larger than

the rest. Dorsal area of each armed with a pair of large spines and a pair of smaller ones. Lateral area of each tergite bearing a spine, at base of which is a small seta. Epipleural lobes each obscurely armed with two minute setæ. Ninth segment armed as usual with two prominent pleural spines.

LIFE HISTORY AND HABITS

The granary weevil normally hibernates during the winter in either the adult or the larval form. The adult is resistant to low temperatures and will survive a very cold winter. Adults resume activity with the first warm weather of spring, and egg laying soon begins. Overwintering larvæ at that time begin pupating. Hibernating adults kept in the laboratory at Washington, D. C., resumed egg laying in the early part of March.

THE ADULT

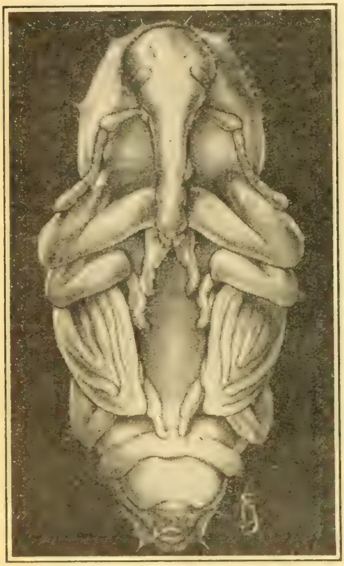

FIG. 8.—The granary weevil: Pupa, ventral view. Enlarged about 37 times

After transformation from the pupal to the adult form, the weevil remains within the seed for a short time until the body integuments harden and the color has changed to a dark chestnut brown. Some weevils remain to feed for a considerable time within the larger seeds. Shortly after emergence copulation takes place and is repeated at frequent intervals throughout the life of the weevil.

The weevils are rather sluggish in their actions and are very easily handled. If disturbed in any way they draw their legs up close to the body and remain motionless for some time. The females may be distinguished from the males by their smoother and more slender beaks.

PARTHENOGENESIS

Virgin females of the granary weevil have been observed to deposit an occasional egg, but none of these hatched.

DURATION OF ADULT LIFE WITHOUT FOOD

The granary weevil is capable of surviving without food for a considerable period, much longer than the closely related rice weevil, possibly because of its less active life and its restriction to a more temperate climate. The temperatures at which the insects were kept under observation had a very marked effect on their powers of resistance to starvation. Five lots of 50 weevils each were kept without food until they died. Each lot was placed in a separate compartment held at a constant temperature. These temperatures ranged from 55° to 85° F. and were maintained with but slight variation for the entire period and at a rather high humidity. The results are given in Table 1.

TABLE 1.—*Resistance of the granary weevil to starvation*

Date	Number of days starved	Number of adult weevils found dead at—					Date	Number of days starved	Number of adult weevils found dead at—				
		55° F.	60° F.	68° F.	76° F.	85° F.			55° F.	60° F.	68° F.	76° F.	85° F.
1920							1920						
June 24	7	0	0	0	12	28	July 12	25	0	7	0	------	------
25	8	5	0	11	12	0	14	27	0	6	3	------	------
26	9	0	0	5	4	4	15	28	0	2	0	------	------
27	10	0	0	0	2	0	16	29	3	0	4	------	------
28	11	0	4	0	14	0	17	30	0	7	0	------	------
29	12	7	7	0	3	7	18	31	2	0	0	------	------
July 1	14	3	0	7	2	2	19	32	0	0	3	------	------
2	15	0	5	0	0	0	20	33	0	3	0	------	------
3	16	0	3	0	1	7	21	34	1	0	2	------	------
4	17	5	2	4	------	1	23	36	0	1	------	------	------
6	19	3	0	0	------	1	29	42	1	------	------	------	------
7	20	2	0	0	------	------	Aug. 3	47	1	------	------	------	------
8	21	4	0	5	------	------	10	54	1	------	------	------	------
9	22	6	3	0	------	------	21	65	1	------	------	------	------
10	23	5	0	6	------	------							

The weevils subjected to a temperature of 85° F. were very active; more than 50 per cent died at the end of the first week of starvation, a few lingered on for some days, and one survived for 19 days. The weevils kept at 55° F. were sluggish; 50 per cent survived for three weeks and one for 65 days.

DURATION OF ADULT LIFE WITH FOOD

The average length of life with food, as indicated by the data in Table 2, is between 7 and 8 months.

This is the average of 35 females observed for oviposition records. Several individuals not included in this table lived considerably longer. Of a number of weevils that emerged on May 1, 1921, one female lived until July 2, 1922, and two females until July 10, 1922, a period of a little more than 14 months. The effect of a moderately low temperature, which permits occasional feeding but at which the adults are decidedly sluggish, is greatly to prolong life. Thus, of 30 adults placed, on September 18, 1921, in a refrigerator of the ordinary type, which maintained a temperature between 50° and 60° F., one lived two years and five months and four were still alive on January 15, 1924. Although adult life may be prolonged to cover a two-year period, it is not likely that conditions favoring such a long life obtain under normal warehouse conditions. The average length of life, as stated above, is about seven or eight months, with certain individuals living well over one year.

PREOVIPOSITION PERIOD

The data of Table 2 indicate that the granary weevil begins ovipositing from 6 to 148 days after emergence. In early spring females begin ovipositing about three weeks after emergences. Later, in the summer, the preoviposition period is reduced to approximately one week. Weevils emerging late in the fall have the longest preoviposition period, since they usually do not begin to oviposit until the following spring.

TABLE 2.—*Data concerning period of oviposition and adult longevity of the granary weevil*

No.	Date weevil emerged	Date first egg was laid	Length of preoviposition period	Date last egg was laid	Length of oviposition period	Number of eggs laid	Date of death	Length of life
	1920	1920	*Days*	1920	*Days*		1920	*Days*
1	Feb. 26	Mar. 19	22	June 14	87	152	June 18	113
2	do	Mar. 18	21	May 29	72	172	June 15	110
3	do	Mar. 24	27	June 11	79	150	June 23	118
4	do	Mar. 20	23	do	83	140	June 18	113
5	do	Mar. 19	22	Aug. 30	164	247	Sept. 1	188
6	May 25	June 2	8	Aug. 31	90	148	Sept. 2	100
7	June 17	June 23	6	Sept. 15	84	170	Sept. 20	95
				1921			1921	
8	Aug. 15	Aug. 27	12	June 10	287	254	June 27	316
9	Aug. 24	Sept. 4	11	Apr. 10	218	77	May 18	267
		1921						
10	Oct. 17	Mar. 3	137	June 30	119	141	Sept. 15	333
11	do	Feb. 24	130	July 22	148	144	Aug. 20	307
	1921			1922			1922	
12	Sept. 5	Sept. 18	13	Apr. 21	215	65	Apr. 25	232
13	Sept. 6	Sept. 19	13	May 12	235	71	May 24	260
14	do	Sept. 15	9	June 12	270	145	June 30	297
15	do	Sept. 18	12	May 8	232	128	May 15	251
16	do	Sept. 15	9	June 7	265	130	June 16	283
		1922						
17	Sept. 7	Feb. 2	148	May 7	94	98	May 25	260
18	Oct. 25	Jan. 28	95	Sept. 24	239	197	Oct. 8	348
19	do	Jan. 31	98	Apr. 21	80	36	May 1	188
20	do	Feb. 1	99	July 24	173	135	Aug. 4	283
21	do	Jan. 30	97	June 5	126	126	June 9	227
22	do	Feb. 1	99	July 28	177	234	July 31	279
23	do	do	99	June 9	128	181	June 12	230
24	do	Feb. 2	100	July 7	155	184	July 17	265
25	do	Feb. 1	99	May 27	115	74	July 10	258
26	do	do	99	Apr. 20	78	114	May 1	188
27	do	Feb. 2	100	June 9	127	200	June 12	230
28	do	Jan. 31	98	June 26	146	177	Aug. 7	286
29	do	Feb. 5	103	Aug. 2	178	166	Aug. 23	302
30	do	Jan. 31	98	May 29	118	210	June 5	223
31	do	Feb. 1	99	Apr. 13	71	95	Apr. 20	177
32	Nov. 7	Mar. 10	123	June 14	96	130	July 21	256
33	Nov. 8	Feb. 18	102	Aug. 6	169	242	Aug. 14	279
34	do	Mar. 19	131	May 25	67	78	June 1	205
35	do	Mar. 6	118	June 5	91	108	July 5	239

METHOD OF EGG LAYING

The beetles lay their eggs within the seeds of most of our common grains. A hole is excavated within the grain equal to the length of the slender proboscis of the female. When this is completed to the satisfaction of the beetle, she withdraws her proboscis and turning around swings the abdomen about until the cavity is located. The ovipositor is then thrust into the cavity and an egg deposited.

Before the ovipositor is withdrawn a translucent mass of gelatinous material is discharged on top of the egg and is tamped down level with the surface of the seed. This plug of gelatinous material quickly hardens, holding the egg in place and forming a protective covering for it.

The eggs are laid in all parts of the seeds but usually near one end. It is probably mechanically easier for the weevil to bore a hole at either end of the seed, owing to the need of a good foothold during the operation.

DAILY RATE OF OVIPOSITION

No data on the daily rate of oviposition of granary weevils of known age have ever been published. Strachov-Koltchin (*65*), after working with weevils of unknown ages and counting the adults emerging from kernels of grain with which they had been confined, published data from which he concluded that, when the average moisture content of the grain was from 15 to 17 per cent, a single egg is deposited at intervals of a few days at a temperature range of 59° to 65.5° F., one egg daily at 63.5° to 70° F., one to two eggs daily at 70° to 75° F., and two to three eggs daily at 75° to 82° F. As this author did not take into consideration the mortality among the immature stages, it is surprising how closely his data agree with those given in Table 3 based upon an actual count [4] of the eggs laid daily by females of known ages.

TABLE 3.—*Daily rate of oviposition of the granary weevil* [a, b, c]

Date of oviposition	Weevil number and oviposition record																								Daily mean temperature
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
1921																									° *F.*
Sept 15			2		1																				78
16			1		1																				77
17			1		1																				79
18	1		1	1	1																				82
19		1	1	1	1																				75
20			1																						73
21			1		1																				75
22	1		1	1	1																				76
23				1	1																				75
24			1		2																				73
25	1		1	2	1																				75
26				2																					71
27				1	1																				69
28	2		1	1	1																				74
29					1																				78
30	1				1																				76
Oct. 1				1	3																				68
2					1																				67
3					1																				68
4					1																				66
1922																									
Jan. 28											1														71
30											1			1											61
31											1	1		1							1		1		75
Feb. 1											1		1	1	1	1		1	1		1		1	1	69
2						1						1		2	1	1	1	1	1	1				1	70
3											2			1		1	1		1	1	2		2	2	63
4						1					1	1		1	2		2	2	2	1	1		1		65
5														1	1	1	1	1	1	1	1	1		2	64
6											1	1		1		1	2		2	2		1	1		61
7															1	1	2	1	1	2		1		1	67
8											1	1			2	1	1	1	1	1	1	2	2		68
9											1				1		1	1	2	2	2	2	1		68
10						1					2			2	1	1	1	1	3	2		1		2	69
11												1		1	1	1	3		2	1	1	1	1	1	68
12												1				2	1		1			3	1	2	68
13						2					1	1		1	1	1	1		1	1		1	1		61
14												2		1			1		1		1	3		2	66
15											1			2	1	2	2		3		1	1	1		65
16						1					2	1		1		1	1		1	2		1	1		69
17						1					1			1	2	1			1		1		1	1	67
18								1			1	2		1	1	1	1	1		1	1	3	3	1	65

[a] No eggs were laid on dates omitted.
[b] Weevils emerged as adults as follows: Nos. 1 to 3 on Sept. 5, Nos. 4 and 5 on Sept. 6, No. 6 on Sept. 7, Nos. 7 to 10 on Nov. 7 and 8, and Nos. 11 to 24 on Oct. 25, 1921.
[c] Nos. 1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, and 24 of Table 3 are the same females recorded in Table 2 as Nos. 12, 13, 14, 15, 16, 17, 32, 33, 34, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, and 31, respectively.

[4] Two kernels of corn were inclosed with a pair of weevils and removed daily and examined beneath the binocular microscope.

TABLE 3.—*Daily rate of oviposition of the granary weevil*—Continued

Date of oviposition	Weevil number and oviposition record																								Daily mean temperature
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
1922																									° F.
Feb. 19														1	1	1	1	1	1	1			1		66
20								1						1	1	1	1	1	1	1		1	2		58
21						2						1		1	2	1	1		2	2	1	1	1	2	69
22								1			1			1	1	1	1			1	1		3		62
23						2		1			1		1	2	1	2		1		1	1		2	1	69
24											2	1		1		1		1	4	2	1	2	1	1	70
25								1			1			2	1	1	1		2	2	1	1	3	1	67
26						1					1	1				1		1		1	1		1	1	60
27						1					1	1		1	1	1		1	1	1	1		2	2	67
28						1					3		1	1	2		2		4	1	1	1	3	1	67
Mar. 1						2		2		1	1			1	1	1		1	1		1	1	2		67
2						1		1			1		1	1	2	1		1	1	1	1	1	2	1	68
3								1		1	1				2		2		2		1		1		65
4								1		1	1	1		1	1		2	3	1	1	1	1		1	69
5								2		1		1	1		1	1	1	1	1		1		2	1	61
6											1	1			1	1		1	1	1	1	1	2	1	66
7								2		1	1			1	2	2	1		1	1	4		1	2	69
8	1					1		3		1	1	1		1	3	2		2	3	2	2	3	4		65
9	1			1				2		1	1	1		1	2	2	2		1	1		1	3	2	66
10	1		1	1	1	1	1	1		1	1			1	1		2	1		1	1	1			67
11	1		1	1	1	1	1	1		1	2		1	2	2		2		2	3			2	2	67
12	1		1	1	1	1	1	1		1				1		1	1		1	1	2			2	59
13			1	1	1	2	1	2		1			1	1	1	2	1	1	1	1	3		1	2	68
14		1	2	1	1	1	2	2		3				2	2	1	1			2	1	1	1	1	70
15	3	2	1	3	1	2	2	2		2	2			2	2	2	2	2	2	2	2		3	1	70
16	2	2	2		2	2	2	2		2	3	1	2	1	2	1	1	1	2	1	1		3	2	69
17	1	2	1	2	2	3	4	2		1	1		2	1	1	2	1		2	2	1	1	2	1	64
18	3	1		2	3	3	2	2		2	3	1	1	1	1	2	1	2		2	2		2	2	67
19	1	1	1	3	2	1	2	1	1	1				1		1				1			1	1	61
20	1	1	1	3	2	1	3	2	1	2				1	1	2			1	1	1		2	2	69
21	1	1	2	2	1	2	1	2	1	1	1	2		1	1	1		1		1			1	1	66
22	1	3	1	4	2	1		2		3	1			1	1	2	2		1	1	1		1	2	67
23		1	4	2	2	2	1	1	2	2					1	1	1	2	3	1	2		2	2	67
24	1	1	4	2	2	1		2	2	3					2	1	2	1	2	1	1		2	2	68
25	2	1	2	4	1	1		3		3	2		2		2	1	2		1	2	2	1	3	3	70
26	1	1		4	1	4		2	2	2				2	3	2	2		2	1	2		5	2	70
27	1	1		3	1	4		2	1	2		1	1	1	2	1	2	1	2	1	1	1	4	2	66
28	2	2	2	3	2	3	2	2		2	3		1		2	1	2	1	3	2	2	2		1	72
29	2	3	3	5	2	1	3	2	1	3	1		4	2	2	5	4	2	2	4	2	1	2	1	70
30		1	1	1		2	2	1		2	2		2	2		2	2	2	2	3	2		1	1	66
31	2	2	1	1	2	3	3	3	2	2	2		1		1	3	3		1	2	2	3	3	3	65
Apr. 1	1		3	1	1	2	1	4	1	2	1		1	2	2	2	2		2	3	2	2	2	2	68
2	2	2	1	2	2	1	2	2	2	1	2		2	2	1	2	1	2	2	3	2	2	2	1	58
3	1	1	2	3	2	2	2	3		2	1	1	1	1	2	3	2	1	2	2	2	1	3	3	65
4	1	2	1	2	3	2	1	2	1	2	1		3	1	3	3	2	2	1	2	3	2	2	2	69
5	2	1	2	2	2	1	3	2	2	1	2		2	2	2	2	3	3	2	2	2	2	5	3	68
6	2	3	2	3	2	3	3	3			1	1	2	1	2	2	2	2	2	3	2	3	2	1	69
7	2	2	2	2	1	2	2	2	2	3	2		2	2	1	1	1	3	3	2	3	2	2	1	68
8	1	2	3	2	2	2	3	2	2		2		3	2	2	2	3	1	2	5	2	2	3	2	75
9	2	1	1	1	2	2	2	1	1	2	1		2	1	2	2	2	2	2	2	2	1	1	2	79
10	2	3	2	3	1	1	2	2		2	2	1	2	2	2	3	2	2	3	2	1	2	4	2	80
11	3	2	2	2	1	2	2	2	2	2	2		1	2	3	2	2	2	2	2	3	2	2	3	80
12	2	2	2	2	2	2	2	3	2	1	1		3	2	2	1	3	1	1	3	2	2	2	2	72
13	2	2	2	2	3	3	2	2	2	2	2		2	1	2	2	2	2	2	2	2	2	3	2	72
14	1	1	2	2	1	1	2	1	1	1	1		1	1	2	2	2		1	2	2	1	2		72
15	1	1	1	3	1	1	2	2	1	1	1		1	1	2	1	1	1	1	3	2	1	1		69
16	1	1	1	2	1	2	2	2	1	1	1		1	1	2	2	2		1	3	1	1	2		66
17	1		2	2	1	1	2	1	1	1	1	1	1	1	2	2	2	1	1	3	2	1	2		68
18	1	2	1	3	2	1	1	2	2	2		2	1	3	2	3	1		1	3	1	2	4		67
19		1	1	2	1	1	1	2	1	1	1	1		2	2	2	1			2	1	1	3		69
20	1	1	1	2	2	1	2	2	2	2	2	1	2	1	1	2	3		1	2	1	2	2		67
21	1			1	2		2	1	1	1	1	1	2		1	2	2			2	1	1	1		68
22				1				1		1					1	1	1				1		1		67
23		1	1	1	1		1	2	1	1					1	1	1				2		2		59
24		1	1	2	1		1	2	1	1			1		2	2	1				2	1	2		64
25		1	1	2	1	1	1	2	1	1	2		2	1	3					2	1	1	2		69
26			1	2	1		3	1		1	2		2	1	2	1				3	1	1	2		73
27			1	1	1	1	3	1	1	1			1		2	1	1			1	1	1	3		71
28		1	1	2	2		1	3	2	1	1		1	1	1	1		1		1	1	1	2		69
29			1	3	1	1	1	2	1	1			1		1	1	2			1	1	1	2		70
30			2	2	2		1	3	1	2	1		1		1	1	1	1		1	1	1	2		67
May 1		1	2	1	2		1	3	1	2			1		1	1	2			2	1	2	3		68
2		1	3	1	1	1	2	2	1	1	2		1	1	1	2	1	1		1	2	2	2		70
3		1	3	1	1		2	2	1	1	1		2	2	1	2	2			1	2	2	3		70
4		1	1	1	1		1	1		1	1		1	1	3	2	2			2		1	2		70
5		1	1	1	1		1	1	1	1	1		1	1	2	2	1			2	1	1	1		71
6			1					2	1		2		1	1	1	1	1			1	1	1	2		71

TABLE 3.—*Daily rate of oviposition of the granary weevil*—Continued

Date of oviposition	Weevil number and oviposition record																								Daily mean temperature
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
1922																									° F.
May 7	---	---	2	1	1	1	1	2	1	1	1	---	2	1	1	1	1	---	---	2	1	1	1	---	73
8	---	---	1	1	1	---	1	2	1	1	2	---	1	1	1	1	1	---	---	1	1	1	2	---	73
9	---	1	1	---	1	---	1	3	1	1	---	---	2	---	1	1	1	---	---	2	3	1	2	---	72
10	---	1	1	---	1	---	1	2	1	1	1	---	1	1	1	1	1	1	---	2	3	1	3	---	72
11	---	1	2	---	2	---	2	2	3	1	3	---	2	3	2	2	2	---	---	2	1	2	1	---	76
12	---	1	3	---	1	---	2	2	3	1	2	---	2	2	2	2	1	1	---	3	1	2	1	---	75
13	---	---	3	---	---	---	---	2	1	---	1	---	1	2	2	---	1	---	---	3	2	1	1	---	74
14	---	---	3	---	1	---	1	2	1	---	1	---	1	2	1	1	1	---	---	3	2	1	2	---	75
15	---	---	3	---	1	---	1	2	1	---	1	---	1	1	2	1	1	---	---	3	2	1	1	---	74
16	---	---	2	---	---	---	---	3	1	1	2	---	2	---	2	2	---	---	---	2	---	2	2	---	73
17	---	---	1	---	1	---	---	2	1	---	2	---	2	1	1	2	1	---	---	2	1	2	1	---	72
18	---	---	2	---	---	---	1	3	1	---	1	---	---	1	2	---	2	---	---	1	---	2	2	---	74
19	---	---	2	---	1	---	---	2	1	---	1	---	---	1	1	1	1	---	---	1	1	2	2	---	70
20	---	---	1	---	1	---	1	2	1	---	1	---	1	---	1	2	2	1	---	1	1	2	2	---	72
21	---	---	2	---	1	---	2	1	2	---	1	---	2	1	2	1	1	---	---	2	1	1	1	---	75
22	---	---	2	---	1	---	1	2	1	---	2	---	---	1	1	2	2	---	---	1	1	2	1	---	78
23	---	---	1	---	---	---	2	2	2	---	1	---	---	1	2	2	2	---	---	1	2	2	2	---	79
24	---	---	1	---	---	---	1	1	1	---	1	---	2	---	2	2	1	---	---	2	1	2	1	---	77
25	---	---	2	---	1	---	2	1	1	---	1	---	1	1	1	1	1	---	---	1	1	2	1	---	76
26	---	---	1	---	---	---	2	2	---	---	2	---	1	1	1	2	2	---	---	1	1	1	1	---	79
27	---	---	2	---	1	---	2	3	---	---	1	---	---	1	2	1	1	1	---	1	2	2	2	---	74
28	---	---	2	---	1	---	1	2	---	---	1	---	2	---	1	2	2	---	---	2	1	2	1	---	67
29	---	---	1	---	1	---	2	1	---	---	1	---	1	---	1	2	1	---	---	1	1	2	1	---	69
30	---	---	1	---	1	---	1	2	---	---	1	---	2	1	2	1	1	---	---	1	1	2	---	---	73
31	---	---	2	---	1	---	1	1	---	---	1	---	2	1	2	1	2	---	---	1	1	2	---	---	75
June 1	---	---	1	---	1	---	2	1	---	1	1	---	1	1	1	2	1	---	---	1	1	2	---	---	74
2	---	---	---	---	---	---	---	2	---	1	1	---	1	---	1	2	2	---	---	1	1	1	---	---	76
3	---	---	---	---	1	---	---	1	---	1	1	---	1	1	1	1	1	---	---	1	2	---	---	---	78
4	---	---	---	---	---	---	---	2	---	1	1	---	1	---	1	2	1	---	---	1	1	---	---	---	77
5	---	---	---	---	1	---	---	1	---	1	1	---	1	1	1	1	1	---	---	1	1	1	---	---	79
6	---	---	---	---	1	---	1	1	---	---	1	---	1	---	1	1	2	---	---	2	2	1	---	---	80
7	---	---	---	---	1	---	1	1	---	---	1	---	1	---	1	2	2	---	---	2	2	1	---	---	83
8	---	---	---	---	---	---	---	3	---	---	2	---	1	---	---	1	3	---	---	2	---	---	---	---	83
9	---	---	1	---	---	---	1	3	---	---	2	---	1	---	1	1	2	---	---	2	---	1	---	---	82
10	---	---	---	---	---	---	1	1	---	---	1	---	---	---	2	---	1	---	---	---	2	1	---	---	84
11	---	---	---	---	---	---	---	1	---	---	1	---	---	---	2	---	1	---	---	---	1	1	---	---	86
12	---	---	1	---	---	---	1	1	---	---	1	---	---	---	2	---	1	---	---	---	2	1	---	---	79
13	---	---	---	---	---	---	---	1	---	---	1	---	---	---	1	---	1	---	---	---	---	---	---	---	73
14	---	---	---	---	---	---	1	1	---	---	1	---	---	---	1	---	1	---	---	---	---	---	---	---	70
15	---	---	---	---	---	---	---	2	---	---	1	---	---	---	1	---	---	---	---	---	1	---	---	---	73
16	---	---	---	---	---	---	---	2	---	---	1	---	---	---	1	---	---	---	---	---	1	1	---	---	78
17	---	---	---	---	---	---	---	---	---	---	1	---	1	---	1	---	---	---	---	---	1	1	---	---	79
18	---	---	---	---	---	---	---	---	---	---	---	---	---	---	2	---	---	---	---	---	---	1	---	---	79
19	---	---	---	---	---	---	---	---	---	---	1	---	1	---	1	---	---	---	---	---	1	1	---	---	78
20	---	---	---	---	---	---	---	---	---	---	1	---	---	---	1	---	---	---	---	---	1	1	---	---	79
21	---	---	---	---	---	---	---	2	---	---	2	---	1	---	2	---	---	---	---	---	---	2	---	---	78
22	---	---	---	---	---	---	---	2	---	---	2	---	1	---	2	---	---	---	---	---	---	1	---	---	74
23	---	---	---	---	---	---	---	---	---	---	1	---	---	---	1	---	---	---	---	---	1	2	---	---	73
24	---	---	---	---	---	---	---	---	---	---	1	---	1	---	1	---	---	---	---	---	1	1	---	---	79
25	---	---	---	---	---	---	---	1	---	---	---	---	---	---	1	---	---	---	---	---	---	1	---	---	82
26	---	---	---	---	---	---	---	1	---	---	---	---	---	---	1	---	---	---	---	---	1	1	---	---	80
27	---	---	---	---	---	---	---	1	---	---	---	---	---	---	2	---	1	---	---	---	---	---	---	---	79
28	---	---	---	---	---	---	---	1	---	---	---	---	---	---	1	---	---	---	---	---	---	---	---	---	81
29	---	---	---	---	---	---	---	---	---	---	1	---	---	---	1	---	---	---	---	---	---	---	---	---	79
30	---	---	---	---	---	---	---	1	---	---	1	---	1	---	1	---	---	---	---	---	---	---	---	---	82
July 1	---	---	---	---	---	---	---	---	---	---	---	---	1	---	1	---	---	---	---	---	---	---	---	---	85
2	---	---	---	---	---	---	---	1	---	---	---	---	1	---	1	---	---	---	---	---	---	---	---	---	86
3	---	---	---	---	---	---	---	1	---	---	---	---	1	---	1	---	1	---	---	---	---	---	---	---	84
4	---	---	---	---	---	---	---	---	---	---	1	---	---	---	---	---	---	---	---	---	---	---	---	---	77
5	---	---	---	---	---	---	---	---	---	---	1	---	1	---	---	---	1	---	---	---	---	1	---	---	70
6	---	---	---	---	---	---	---	2	---	---	1	---	---	---	1	---	---	---	---	---	---	---	---	---	73
7	---	---	---	---	---	---	---	2	---	---	1	---	1	---	1	---	1	---	---	---	---	---	---	---	72
8	---	---	---	---	---	---	---	---	---	---	1	---	---	---	---	---	---	---	---	---	---	---	---	---	79
9	---	---	---	---	---	---	---	2	---	---	1	---	1	---	1	---	---	---	---	---	---	---	---	---	80
10	---	---	---	---	---	---	---	2	---	---	1	---	1	---	1	---	---	---	---	---	---	1	---	---	79
11	---	---	---	---	---	---	---	1	---	---	---	---	1	---	1	---	---	---	---	---	---	---	---	---	82
12	---	---	---	---	---	---	---	1	---	---	---	---	1	---	1	---	---	---	---	---	---	---	---	---	88
14	---	---	---	---	---	---	---	---	---	---	---	---	1	---	1	---	---	---	---	---	---	---	---	---	75
15	---	---	---	---	---	---	---	---	---	---	1	---	---	---	1	---	---	---	---	---	---	---	---	---	73
16	---	---	---	---	---	---	---	---	---	---	---	---	1	---	1	---	---	---	---	---	---	---	---	---	77
17	---	---	---	---	---	---	---	---	---	---	1	---	---	---	1	---	---	---	---	---	---	---	---	---	79
18	---	---	---	---	---	---	---	1	---	---	1	---	---	---	2	---	---	---	---	---	---	---	---	---	80
19	---	---	---	---	---	---	---	1	---	---	1	---	---	---	1	---	---	---	---	---	---	---	---	---	80
20	---	---	---	---	---	---	---	1	---	---	1	---	1	---	2	---	---	---	---	---	---	---	---	---	78
21	---	---	---	---	---	---	---	1	---	---	1	---	---	---	1	---	---	---	---	---	---	---	---	---	76
22	---	---	---	---	---	---	---	1	---	---	---	---	1	---	2	---	---	---	---	---	---	---	---	---	79
23	---	---	---	---	---	---	---	1	---	---	1	---	1	---	2	---	---	---	---	---	---	1	---	---	82
24	---	---	---	---	---	---	---	1	---	---	---	---	1	---	2	---	---	---	---	---	---	---	---	---	87

TABLE 3.—*Daily rate of oviposition of the granary weevil*—Continued

Date of oviposition	Weevil number and oviposition record																								Daily mean temperature
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
1922																									° F.
July 25								1																	80
26								1																	75
27								1			1				1										77
28								1							1										81
29								1																	79
30								2			1											1			79
31								1																	77
Aug. 1											1														78
2											1											1			77
4											1														77
6								1																	80
8											1														78
9											1														72
23											1														75
25											1														76
Sept. 1											1														76
3											1														75
5											1														80
9											1														77
10											1														78
14											1														74
15											1														77
17											1														70
19											1														68
20											1														69
23											1														70
24											1														73
Total eggs	65	71	145	128	130	98	130	242	78	108	197	36	135	126	234	181	184	74	114	200	177	166	210	95	

During the experiments recorded in Table 3 the average moisture content of the grain (corn) was about 12 to 14 per cent. It will be noted that from one to five eggs were laid per day when oviposition took place; 58.4 per cent of the 2,199 records of oviposition were for one egg per day, 33.4 per cent for two eggs per day, 7 per cent for three eggs per day, 0.9 per cent for four eggs per day, and 0.3 per cent for five eggs per day. On the 5 days when five eggs per day were laid the mean temperatures were 70°, 70°, 68°, 69°, and 75° F. and not more than two of the females under observation deposited so large a number of eggs on any one day. On the 19 days when four eggs were deposited each day, the mean temperatures were 70°, 67°, 69°, 65°, 64°, 67°, 67°, 68°, 70°, 70°, 70°, 66°, 66°, 70°, 70°, 70°, 68°, 80°, and 67° F. The more usual number of eggs deposited per day appears to be one or two. In one instance when the mean temperature fell as low as 58° F., 6 females deposited one egg each, 16 females deposited two eggs each, and 1 female deposited three eggs. When these records were made (April 2) the female weevils were in the midst of spring activity. Earlier in the year, on February 20, when the mean temperature was 58° F., but at the beginning of spring oviposition, 9 females deposited one egg each and only 1 female two eggs. One female, No. 20, on two occasions deposited three eggs for four consecutive days when the temperature means were 69°, 66°, 68°, and 67° F., and 75°, 74°, 75°, and 74° F. It is interesting to note, however, that during the latter period of four days when a second female (No. 3) also deposited three eggs each day, other records show but one egg deposited in 32 instances, two eggs in 19 instances, and three eggs in only 1 instance. A female, No. 11, deposited only a single egg per day on the 39 oviposition

days between June 23 and September 25, when she died, although the temperature means for this period ranged from 68° to 88° F. and averaged well above 70° F. This female, which began ovipositing on January 28, was therefore nearing the end of her life; still she deposited but one egg on each of 120 oviposition days, two eggs on each of 31 oviposition days, and three eggs on each of 5 oviposition days.

In the absence of definite data on the normal larval mortality, it is believed to be rather high, and this is thought by the writers to account for the somewhat higher daily rate of oviposition recorded in Table 3 as compared with the conclusion of Strachov-Koltchin (*65*).

DURATION OF OVIPOSITION

The duration of the oviposition period is influenced by several factors and varies considerably. (See Tables 2 and 3.) Those adults that emerge late in the season and commence egg laying in the fall have a long oviposition period. They cease ovipositing on the approach of cold weather and commence again in the spring, during February or March. Thus weevil No. 3, of Table 3, emerging on September 5, began ovipositing September 15, and oviposited almost daily until September 28, when she ceased laying until March 10, only to resume egg laying and to continue it almost daily until June 1, ceasing entirely on June 12. This record of duration of oviposition of 270 days is second only to that of 287 days, August 27, 1920, to June 10, 1921, by a female depositing 254 eggs. (No. 8, Table 2.)

Adults emerging in the spring have a shorter oviposition period, because they deposit all their eggs during a single season. The shortest oviposition period recorded in Table 3 is 67 days, Weevil No. 9, March 19 to May 25, 1922. Weevil No. 11 of Table 3, depositing a total of 197 eggs, emerged on October 25, 1921, but did not begin ovipositing until January 28, 1922, after which she laid eggs with considerable regularity until September 24, 1922, thus having an oviposition period of 239 days. Weevil No. 8, with an egg-laying capacity of 242, emerged November 7, 1921, began ovipositing February 18, 1922, and continued until August 6, 1922, an oviposition period of 169 days.

The average length of the oviposition period for adults emerging during the spring and early summer is between three and four months.

NUMBER OF EGGS DEPOSITED BY SINGLE FEMALES

The data of Strachov-Koltchin, which are the only data previously published on the egg-laying capacity of the granary weevil, were obtained with promiscuously captured females. From 11 females he secured 65, 78, 87, 107, 116, 121, 129, 135, 149, 153, and 167 eggs respectively. But he concluded that "since the females used were in most cases not young, it is possible to assume that a normal number of eggs deposited by a single female during her life is 135 to 167."

The 24 females of known ages, the oviposition records of which are given in Table 3, deposited totals of 36, 65, 71, 74, 78, 95, 98, 108, 114, 126, 128, 130, 130, 135, 145, 166, 177, 181, 184, 197, 200, 210, 234, and 242. The largest number of eggs deposited by any single female recorded is 254 (Table 2, No. 8). In Table 2 are recorded the total numbers of eggs deposited by 35 females, the daily oviposition records of 24 of which are given in Table 3.

THE EGG

INCUBATION PERIOD

Data on the incubation period of the granary weevil accompanied by the maximum, minimum, and mean temperatures for the period, have never been published. References to the length of the egg stage are very fragmentary except those by Strachov-Koltchin (*65*), in which the day, but not the night, temperatures are given. This writer concludes that the incubation period may range from about 5 days at 75° F. to 15 days at 62° F. Observations made on individual eggs indicated that at 75° F. the incubation period might be 5 to 6 days; at 73° and 82° F., 6 days; at 69° F., 8 days; at 68° F., 9 days; and at 67° F., 9 to 10 days.

TABLE 4.—*Duration of the egg stage of the granary weevil*

No.	Date egg laid	Date egg hatched	Temperature for incubation period: Maximum	Minimum	Mean	Length of egg stage	No.	Date egg laid	Date egg hatched	Temperature for incubation period: Maximum	Minimum	Mean	Length of egg stage
	1919	1919	°F.	°F.	°F.	Days		1920	1920	°F.	°F.	°F.	Days
1	Sept. 30	Oct. 5	98	67	79.8	5	23	Sept. 2	Sept. 6	96	68	81.5	4
2	Oct. 1	do	98	68	78.0	4	24	Sept. 3	Sept. 8	95	68	82.8	5
3	Oct. 2	Oct. 6	98	68	83.1	4	25	Oct. 5	Oct. 12	89	50	70.9	7
4	Oct. 3	Oct. 7	98	67	83.1	4	26	Nov. 7	Nov. 13	88	57	72.1	6
5	Oct. 15	Oct. 19	94	67	80.4	4	27	Nov. 12	Nov. 17	79	57	68.5	5
	1920	1920						Nov. 15	Nov. 20	76	39	62.9	5
6	Mar. 18	Mar. 24	90	54	69.7	6	28	Dec. 4	Dec. 19	84	35	61.0	15
7	Mar. 25	Mar. 31	95	52	76.8	6	29	Dec. 15	Dec. 25	84	35	60.0	10
8	Mar. 26	Apr. 1	95	58	77.5	6	30	Dec. 16	Dec. 24	84	35	61.2	8
9	Mar. 28	Apr. 3	95	55	78.1	6	31	1921	1921				
10	Apr. 9	Apr. 15	85	46	66.6	6	32	Jan. 11	Jan. 20	80	34	61.2	9
11	Apr. 13	Apr. 18	90	46	68.7	5	33	Jan. 21	Jan. 30	84	43	62.6	9
12	Apr. 16	Apr. 21	92	54	76.1	5	34	Jan. 23	Feb. 1	84	43	64.0	9
13	Apr. 20	Apr. 25	93	62	78.9	5	35	Jan. 31	Feb. 12	88	43	67.6	12
14	June 23	June 27	93	69	79.9	4	36	Feb. 2	Feb. 14	88	39	66.2	12
15	June 26	June 30	93	66	78.6	4	37	Feb. 3	Feb. 15	88	39	66.5	12
16	July 3	July 7	96	70	82.9	4	38	Feb. 11	Feb. 23	86	39	65.2	12
17	July 14	July 18	94	68	81.0	4	39	July 26	July 30	----	----	85.4	4
18	July 15	July 20	94	68	81.3	5	40	July 30	Aug. 3	----	----	81.5	4
19	July 20	July 24	94	70	81.5	4	41	Aug. 2	Aug. 6	----	----	83.5	4
20	July 24	July 28	95	68	80.5	4	42	Aug. 15	Aug. 20	86	69	76.5	5
21	Aug. 5	Aug. 9	93	69	80.2	4	43	Sept. 26	Oct. 1	83	65	72.5	5
22	Sept. 1	Sept. 5	96	68	81.6	4							

Of the data presented by the writers in Table 4, those for 1919 and 1920 were secured under the semitropical conditions of Florida and those of 1921 under laboratory conditions at Washington, D. C. These data indicate that the minimum period for egg development is 4 days when the temperature means average about 78° to 80° F. The longest incubation period, 15 days, recorded in Table 4, covers a period when the daily temperatures ranged from a minimum of 35° F. to a maximum of 84° F., with a mean of 61° F. But at a mean of 60° F., with the same range in the maximum and minimum temperatures for the period, one egg (No. 30) required only 10 days for development. Certain eggs held for 28 days in refrigeration at

30° F., and then removed to a warm temperature, hatched 32 days after deposition. Although 4 days is the minimum period observed by the writers, eggs have been observed to hatch in 5 days after deposition when the temperature for the incubation period ranged from a mean of 68.7° F. (90° F. maximum, 46° F. minimum) and of 82.8° F. (95° F. maximum, 68° F. minimum).

Although the data of Table 4 indicate that the length of the incubation period is from 4 to 15 days under more normal conditions and may be extended over a period of at least 32 days during colder weather, there are dealers in grain who firmly believe that eggs are capable of passing through a very long period of development, and that they are capable of a suspended development when temperature conditions are unfavorable to growth, only later to resume normal development upon the return of favorable temperature conditions. It has been found that the female weevils do not begin to mate and lay eggs until the temperature is from 61° to 63° F., and that even at these temperatures eggs are not deposited every day. It is not until the temperature has risen to 66° to 68° F. that mating and oviposition occur daily. It would appear from observations that eggs are not deposited at temperatures below the minimum at which they can start development. Should the temperature drop to below 50° to 55° F. for a considerable period, there is every reason to believe that egg development is suspended indefinitely and that eggs perish for lack of warmth. No eggs were observed to hatch after the temperature of the grain had reached 95° F. or above.

THE LARVA

When the embryo is fully developed, its undulating movements cause a rupture of the thin eggshell, and the young larva emerges to find an abundance of food ready at hand. It immediately begins to feed, burrowing through the tissues of the seed, forming a winding tunnel that increases in size with the growth of the larva. The tunnel is often close to the surface of the seed, and in corn, particularly, the progress of the larva is sometimes distinctly visible through the seed coat (fig. 4).

FOOD OF THE LARVA

The larva breeds in all the common grains, such as corn (fig. 4), oats, barley (fig. 2), rye, wheat (fig. 3), kafir, buckwheat, millet, and also in chick-peas (fig. 9). It is said to breed in acorns, chestnuts, and sunflower seeds, although Strachov-Koltchin states that he failed to get them to breed in sunflower seeds. It is unable to breed in loose farinaceous material, such as flour and semolina used in making macaroni, but breeds readily in manufactured products of cereals, such as macaroni (fig. 5), noodles, and probably other similar products, and in milled cereals that have become badly caked from excess moisture. The larva feeds on all parts of the seed, but prefers the soft starchy portion. As it bores and tunnels through the seed it thrusts the borings and frass behind it, so that the mine it leaves behind is always filled. It has been found that larvæ can feed in grain with a moisture content as low as 8 per cent, although feeding undoubtedly progresses more normally when the moisture content is about 14 to 16 per cent.

TABLE 5.—*Duration of larval stage of the granary weevil*

No.	Date larvæ hatched	Date of first molt	Length of first instar	Mean temperature	Date of second molt	Length of second instar	Mean temperature	Date of third molt	Length of third instar	Mean temperature	Date prepupal stage began	Length of fourth instar	Mean temperature	Date larva pupated	Length prepupal stage	Mean temperature	Length larval stage	Mean temperature Maximum	Mean temperature Minimum
	1919	1919	Days	°F.	1919	Days	°F.	1919	Days	°F.	1919	Days	°F.	1919	Days	°F.	Days	°F.	°F.
1	Oct. 5	Oct. 9	4	82	Oct. 13	4	81	Oct. 17	4	80	Oct. 24	7	80	Oct. 25	1	82	20	93	67
2	do	Oct. 10	5	82	Oct. 14	4	81	Oct. 21	7	81	Oct. 30	9	80	Nov. 1	2	80	27	93	67
3	Oct. 6	do	4	82	do	4	80	Oct. 18	4	80	Oct. 26	8	81	Oct. 27	1	79	21	93	67
4	Oct. 7	Oct. 11	4	82	Oct. 15	4	79	Oct. 20	5	81	Oct. 31	11	79	Nov. 1	1	81	25	93	67
5	Oct. 19	Oct. 23	4	80	Oct. 27	4	80	Oct. 31	4	78	Nov. 9	9	76	Nov. 10	1	72	22	91	65
	1920	1920			1920			1920			1920			1920					
6	Mar. 24	Mar. 29	5	74	Apr. 5	7	78	Apr. 15	10	66	Apr. 25	10	76	Apr. 26	1	78	33	87	62
7	Mar. 31	Apr. 8	8	72	Apr. 14	6	68	Apr. 22	8	73	Apr. 29	7	78	Apr. 30	1	69	30	84	61
8	Apr. 1	do	7	72	Apr. 15	7	68	Apr. 21	6	73	Apr. 27	6	79	Apr. 28	1	74	27	84	61
9	Apr. 3	Apr. 10	7	69	Apr. 16	6	66	Apr. 22	6	76	Apr. 28	6	79	Apr. 29	1	67	26	84	61
10	Apr. 15	Apr. 21	6	73	Apr. 27	6	79	May 2	5	73	May 8	6	74	May 9	1	73	24	87	63
11	Apr. 18	Apr. 24	6	79	Apr. 28	4	80	May 3	5	73	May 11	8	74	May 12	1	72	24	87	63
12	Apr. 21	Apr. 26	5	75	Apr. 30	4	78	May 5	5	76	May 12	7	74	May 13	1	75	22	87	63
13	Apr. 25	Apr. 30	5	74	May 5	5	75	May 10	5	74	May 18	8	76	May 19	1	73	24	87	63
14	June 27	July 1	4	78	July 5	4	83	July 9	4	82	July 15	6	84	July 16	1	81	19	93	70
15	June 30	July 4	4	82	July 9	5	83	July 14	5	84	Aug. 2	19	81	Aug. 3	1	82	34	93	70
16	July 7	July 11	4	83	July 15	4	84	July 19	4	81	July 25	6	82	July 26	1	80	19	93	70
17	July 18	July 22	4	82	July 27	5	81	July 31	4	81	Aug. 13	13	81	Aug. 14	1	82	27	93	70
18	July 20	July 24	4	82	July 28	4	81	Aug. 1	4	81	Aug. 8	7	81	Aug. 9	1	80	20	93	70
19	July 24	July 28	4	81	Aug. 1	4	81	Aug. 5	4	81	Aug. 18	13	81	Aug. 19	1	82	26	93	70
20	July 28	Aug. 1	4	81	Aug. 5	4	81	Aug. 10	5	80	Aug. 20	10	81	Aug. 21	1	80	24	93	70
21	Aug. 9	Aug. 13	4	82	Aug. 17	4	81	Aug. 22	5	81	Aug. 31	9	83	Sept. 1	1	82	23	93	70
22	Sept. 5	Sept. 9	4	82	Sept. 15	6	84	Sept. 20	5	80	Sept. 27	7	80	Sept. 28	1	80	23	92	70
23	Sept. 6	Sept. 11	5	82	do	4	85	Sept. 21	6	80	Sept. 29	8	79	Sept. 30	1	75	24	92	70
24	Sept. 8	Sept. 14	6	84	Sept. 19	5	81	Sept. 26	7	80	Oct. 9	13	73	Oct. 10	1	68	32	91	65
25	Oct. 12	Oct. 18	6	74	Oct. 23	5	77	Oct. 28	5	76	Nov. 9	12	69	Nov. 10	1	74	29	86	61
											1921			1921					
26	Nov. 13	Nov. 21	8	64	Nov. 30	9	64	Dec. 12	12	62	Jan. 2	21	61	Jan. 3	1	69	51	77	51
27	do	Nov. 22	9	64	Dec. 2	10	60	do	10	61	Jan. 5	24	63	Jan. 7	2	66	55	77	51
28	Nov. 17	Nov. 25	8	62	Dec. 8	13	63	Dec. 25	17	61	Jan. 14	20	64	Jan. 15	1	62	59	77	49
29	Nov. 20	Nov. 29	9	63	Dec. 9	10	64	Dec. 22	13	60	Jan. 10	19	65	Jan. 12	2	61	53	77	49
					1921			1921											
30	Dec. 19	Nov. 31	12	62	Jan. 9	9	67	Jan. 17	8	61	Jan. 28	11	63	Jan. 29	1	60	41	76	49
		1921																	
31	Dec. 25	Jan. 3	9	61	Jan. 12	9	66	Jan. 23	11	62	Feb. 1	9	63	Feb. 3	2	63	40	77	50
32	Dec. 24	do	10	61	Jan. 16	13	65	Jan. 25	9	63	Feb. 10	16	65	Feb. 12	2	67	50	76	51

	1921																		
33	Jan. 20	Jan. 31	11	63	Feb. 12	12	66	Feb. 22	10	64	Mar. 2	8	59	Mar. 3	1	64	42	78	50
34	Jan. 30	Feb. 11	12	68	Feb. 22	11	64	Mar. 2	8	59	Mar. 12	10	68	Mar. 13	1	75	42	80	51
35	Feb. 1	Feb. 13	12	61	Feb. 23	10	64	Mar. 4	9	60	do	8	70	do	1	75	40	80	51
36	Feb. 12	Feb. 23	11	63	Mar. 9	14	62	Mar. 19	10	76	Mar. 27	8	75	Mar. 28	1	76	44	83	55
37	Feb. 14	Feb. 24	10	64	do	13	62	Mar. 16	7	75	Mar. 24	8	76	Mar. 25	1	76	39	83	55
38	Feb. 15	Feb. 23	8	65	Mar. 3	8	59	Mar. 12	9	71	do	12	76	do	1	76	38	83	55
39	Feb. 23	Mar. 2	7	59	Mar. 10	8	67	Mar. 19	9	76	Apr. 3	15	75	Apr. 4	1	72	40	85	57
																		Mean	
40	July 30	Aug. 4	5	81	Aug. 9	5	81	Aug. 15	6	77	Aug. 27	12	74	Aug. 28	1	73	29	77	
41	Aug. 3	Aug. 7	4	82	Aug. 11	4	78	Aug. 16	5	77	do	11	75	do	1	73	25	77	
42	Aug. 6	Aug. 10	4	80	Aug. 15	5	77	Aug. 19	4	75	Aug. 28	9	75	Aug. 29	1	77	23	77	
43	Aug. 20	Aug. 24	4	77	Aug. 29	5	73	Sept. 4	6	84	Sept. 16	12	80	Sept. 17	1	78	28	78	
44	Oct. 1	Oct. 7	6	68	Oct. 12	5	70	Oct. 19	7	71	Oct. 30	11	71	Oct. 31	1	71	30	69	

LENGTH OF LARVAL STAGE

The length of the larval stage is influenced chiefly by temperature and moisture. With a good food supply of normal moisture content the larval stage during summer months was found to last from 19 to 34 days. Individual larvæ showed considerable difference in the length of the developmental period; thus two larvæ completed their development during summer in 19 and 34 days, respectively, when the mean temperatures ranged from a maximum of 93° F. to a minimum of 70° F. The longest larval development recorded by the writers is 59 days, when the mean temperatures varied from 77° to 49° F. The development of 44 larvæ is recorded in Table 5. In Russia Strachov-Koltchin (*65*) found that the period for larval development varied from 21½ to 84 days, according to the temperature.

NUMBER AND DURATION OF LARVAL INSTARS

FIG. 9.—Chickpeas sectioned to reveal honeycombing of interior of seed by feeding of larvæ and adults of the granary weevil

The larva of the granary weevil molts three times at more or less regular intervals. The first three instars are usually about equal in length; the fourth is somewhat longer. During summer weather the first three instars are of from 4 to 5 days' duration and the fourth lasts from 6 to 19 days. The duration of the larval instars with the mean temperature for the period is given in Table 5.

These data indicate that the first larval instar was from 4 to 12 days in length when the temperature means were from 84° to 61° F.; the second instar from 4 to 14 days in length when the means varied from 84° to 59° F.; the third instar from 4 to 17 days in length when the mean temperatures for the period varied from 84° to 59° F.; the fourth larval stage from 6 to 24 days when the temperature means varied from 84° to 59° F.

THE PUPA

After attaining its growth the larva prepares a pupal cell at the end of its burrow, using a mixture of frass, borings, and larval secretions to wall in the open end of its burrow. If the cell is accidentally broken open before the larva has transformed, the break is repaired. After the cell is completed, the larva assumes a prepupal form that normally lasts for one day in summer or two days in colder weather before it transforms to the pupal stage. Data regarding the length of the pupal stage are given in Table 6.

TABLE 6.—*Duration of the pupal stage of the granary weevil*

No.	Date of—		Length pupal stage	Mean temperatures		No.	Date of—		Length pupal stage	Mean temperatures	
	Pupation	Emergence		Maximum	Minimum		Pupation	Emergence		Maximum	Minimum
	1919		*Days*	°*F.*	°*F.*		1920		*Days*	°*F.*	°*F.*
1	Oct. 25	Oct. 30	5	91	66	24	Oct. 10	Oct. 16	6	88	58
2	Nov. 1	Nov. 6	5	86	66	25	Nov. 10	Nov. 18	8	74	57
3	Oct. 27	Nov. 1	5	91	67						
4	Nov. 1	Nov. 6	5	86	66		1921				
5	Nov. 10	Nov. 17	7	81	59	26	Jan. 3	Jan. 13	10	79	52
						27	Jan. 7	Jan. 16	9	75	48
	1920					28	Jan. 15	Jan. 31	16	75	48
6	Apr. 26	May 3	7	86	64	29	Jan. 12	Jan. 22	10	77	49
7	Apr. 30	May 6	6	88	62	30	Jan. 29	Feb. 12	14	79	53
8	Apr. 28	May 4	6	85	61	31	Feb. 3	Feb. 13	10	79	54
9	Apr. 29	May 5	6	87	61	32	Feb. 12	Feb. 23	11	80	47
10	May 9	May 15	6	89	62	33	Mar. 3	Mar. 18	15	78	59
11	May 12	May 18	6	88	65	34	Mar. 13	Mar. 23	10	90	61
12	May 13	do	5	88	66	35	do	Mar. 21	8	91	62
13	May 19	May 24	5	88	63	36	Mar. 28	Apr. 5	8	85	62
14	July 16	July 22	6	93	71	37	Mar. 25	Apr. 2	8	87	63
15	Aug. 3	Aug. 10	7	91	70	38	do	Apr. 1	7	87	63
16	July 26	Aug. 1	6	92	70	39	Apr. 4	Apr. 10	6	89	60
17	Aug. 14	Aug. 21	7	93	69					Mean	
18	Aug. 9	Aug. 15	6	94	70	40	Aug. 28	Sept. 3	6	82	
19	Aug. 19	Aug. 25	6	95	69	41	do	Sept. 2	5	82	
20	Aug. 21	Aug. 27	6	95	69	42	Aug. 29	Sept. 3	5	84	
21	Sept. 1	Sept. 6	5	93	70	43	Sept. 17	Sept. 22	5	77	
22	Sept. 28	Oct. 3	5	82	60	44	Oct. 31	Nov. 7	7	68	
23	Sept. 30	Oct. 6	6	81	59						

These data indicate that during the warm season of the year, when the mean temperatures vary from a maximum of 85° to 95° F. to a minimum of 61° to 71° F., the pupal stage may require a minimum of 5 days for development. During the hottest summer weather pupal development was completed in from 5 to 7 days. Certain pupæ completed their development in 5, 6, and 7 days when the mean temperature was 77°, 82°, and 68° F., respectively. During the colder season six pupæ completed their development in 16, 10, 14, 10, 11, and 15 days when the mean temperatures were 61.5°, 63°, 66°, 66.5°, 63.5°, and 68.5° F., respectively.

LENGTH OF DEVELOPMENTAL PERIOD

The length of the developmental period of the granary weevil is comparatively short during moderately warm weather. The cycle from egg to adult is recorded in Table 7.

TABLE 7.—*Duration of the developmental period of the granary weevil*

No.	Number of days in —			Number of days from egg to adult	Mean temperature for period	No.	Number of days in —			Number of days from egg to adult	Mean temperature for period
	Egg stage	Larval stage	Pupal stage				Egg stage	Larval stage	Pupal stage		
					° F.						° F.
1	5	20	5	30	80.4	23	4	24	6	34	80.0
2	4	27	5	36	80.4	24	5	32	6	43	77.3
3	4	21	5	30	80.4	25	7	29	8	44	70.4
4	4	25	5	34	80.4	26	7	51	10	68	64.3
5	4	22	7	33	77.0	27	6	55	9	70	64.3
6	6	33	7	46	72.9	28	5	59	16	80	62.9
7	6	30	6	42	73.6	29	5	53	10	68	62.9
8	6	27	6	39	73.6	30	15	41	14	70	62.9
9	6	26	6	38	73.6	31	10	40	10	60	63.3
10	6	24	6	36	74.0	32	8	50	11	69	63.1
11	5	24	6	35	74.7	33	9	42	15	66	65.7
12	5	22	5	32	75.5	34	9	42	10	61	66.0
13	5	24	5	34	75.3	35	9	40	8	57	66.7
14	4	19	6	29	80.5	36	12	44	8	64	67.0
15	4	34	7	45	81.0	37	12	39	8	59	68.6
16	4	19	5	28	81.5	38	12	38	7	57	68.6
17	4	27	7	38	81.5	39	12	40	6	58	69.7
18	5	20	6	31	81.5	40	4	29	6	39	79.0
19	4	26	6	36	81.5	41	4	25	5	34	79.0
20	4	24	6	34	81.5	42	4	23	5	32	79.0
21	4	23	5	32	81.5	43	5	28	5	38	78.1
22	4	23	5	32	79.3	44	5	30	7	42	70.0

Several specimens were reared from egg to adult in 28 days, and this together with a preoviposition period of about 7 days would give a possible complete life cycle from egg to egg of 35 days. This, however, is a much shorter life cycle than normal, for in summer the average length of the period from egg to adult, as shown in Table 7, is between 30 and 40 days, and the preoviposition period may be as short as 6 days in midsummer or, when the adult emerges in the fall or early winter, as long as 123 or 148 days. In the vicinity of Washington, D. C., there are between three and four generations a year.

RESISTANCE TO HIGH TEMPERATURES

As already recorded by the writers (*3*), the granary weevil is not very resistant to high temperatures. Exposure for a very few hours to 115° F., for one hour to 118° to 120° F., or for 30 minutes to 130° F., will kill all stages. Moderately high temperatures also are fatal to the granary weevil if maintained for any length of time. Of adults placed in an incubator maintained at 95° F., four-fifths died on the fifth day of exposure, a few survived for 9 days, and one for 13 days. Little, if any, feeding occurred during this period and no eggs were laid. Eggs incubated at 95° F. failed to hatch, and larvæ exposed to this temperature did not complete their development.

RESISTANCE TO LOW TEMPERATURES

The granary weevil prefers a cool climate in which to breed and is much more resistant to low temperatures than is the rice weevil.

The effect of a moderately low temperature is to prolong the life of the adult weevil. As already recorded by the writers (*3*), a few of the weevils placed in an ordinary refrigerator with a temperature that ranged between 50° and 60° F. lived for a period of 29 months. They were almost inactive at this temperature but fed occasionally. When kept at a temperature of 35° to 40° F. a few adults lived as long as 111 days, whereas at temperatures ranging from 40° to 45° F. adults survived for 105 days. A temperature of 30° to 35° F. proved fatal to adults of the granary weevil after 73 days. A temperature of 25° to 30° F. killed all adults within 46 days. At 20° to 25° F. all adults were dead at the end of 33 days; at 15° to 20° F., at the end of 14 days; at 5° F., at the end of 7½ hours. A constant temperature of zero proved fatal to adults of the granary weevil at the end of an exposure of 5 hours.

Twenty per cent of the eggs of the granary weevil survived an exposure to a constant temperature of 30° F. for 28 days. Larvæ exposed to this temperature survived for 44 days.

PARASITES

The granary weevil is attacked by several parasitic Hymenoptera while in the larval and pupal stages. The two most commonly observed in North America are *Aplastomorpha calandrae* Howard and *Chaetospila elegans* Westw., while *Lariophagus distinguendus* Forst. is apparently the most abundant parasite of the granary weevil in Europe. Goodrich (*34*), in 1921, wrote regarding parasites of beetles infesting grain.

A predacious mite, *Pediculoides ventricosus* Newport, frequently attacks the egg, larva, and pupa of the granary weevil.

CONTROL MEASURES

Control measures consist chiefly in the use of heat, cold, and fumigants. The use of heat, in the ordinary grain heating and drying equipment on the market, seems not to be popular with grain dealers since grain is purchased by weight and heating results in the loss of moisture. A temperature of 118° F. to 120° F. for one hour or of 130° F. for 30 minutes kills all stages of the weevil actually subjected to it. It should not be forgotten that the grain must be heated sufficiently to allow the proper amount of heat to penetrate to the insects concealed within. In quarantine work the Federal Horticultural Board has found it advisable to require that corn entering this country from Mexico be subjected to a temperature of 200° F. for at least five minutes to insure freedom from insect pests.

Dean (*15*) and Goodwin (*33*) have published on heat control.

Carbon disulphide is the only fumigant at present in general use in the United States for killing weevils in grain in bulk. When carbon disulphide is used at the rate of from 5 to 15 pounds per 1,000 bushels, according to the tightness of the crib, the granary weevil can be killed in all stages. Carbon tetrachloride alone and ethyl acetate-carbon tetrachloride mixture (*47*) vary in effectiveness and must be used from two to four times as strong as carbon disulphide. The ethyl acetate-carbon tetrachloride mixture, however, is not entirely satisfactory to the grain trade on account of an odor which this mixture may leave.

The running of grain from bin to bin during very cold weather has been practiced. The writers observed this method of reducing the temperature of grain during the war period when wheat, in being transferred, was allowed to fall through the air during zero weather from a height of about 25 feet. If grain can be sufficiently chilled by running, it can be protected from weevil attack. Even if its temperature can not be lowered to the point where the cold will prove fatal to the insect's life, much good will result from the suspension of its activity.

Since the control of the granary weevil is not different from that of grain pests in general, no further discussion of control measures is given.

SUMMARY

The granary weevil, *Sitophilus granarius* L., has been known as a grain pest from ancient times. Recognized as a distinct species by Linné in 1758, it has since been discussed as a pest of economic importance by many writers but has not been studied seriously, from a biologic standpoint, until within the last few years. It is often confused with, though easily distinguished from, the closely related and more destructive rice weevil, *Sitophilus oryza* L.

The granary weevil is considered to have originated in either Asia or the Mediterranean region. Unlike other members of the genus Sitophilus, however, which thrive best in tropical and semitropical climates, the granary weevil is now distinctly a temperate-climate species with a world-wide distribution. In the United States it appears to be giving way to *Sitophilus oryza*, and to be the prevailing calandrid species only in the more northern States.

Provided with no effective wings and by nature not very active, the granary weevil is found primarily in the granary or storehouse and depends upon man for dissemination. It does not appear to be well equipped to meet present-day methods of handling and protecting grain, with the result that, in the United States at least, it seems to be losing some of its importance as a pest in grain and certain grain products.

Like calandrid pests in general, the granary weevil causes the destruction of grain and grain products by the direct feeding of the adult beetle and its larva. Adult beetles, being long-lived and voracious, devour much grain throughout their life. They feed not only upon whole grains but upon stock feeds containing cracked grain and even upon finely divided products such as flours. The larvæ feed upon whole grains or upon portions of grains sufficiently large to support the larva throughout its entire development. Although larvæ will not develop in finely divided cereal products such as flours and meals, they can probably develop in these when they become caked from one cause or another. The adult weevils occasionally are destructive by boring holes in the cartons of packaged cereals.

The granary weevil hibernates during the winter months as adult or larva. With the approach of warm spring weather, the adults begin to oviposit and the larvæ to feed and transform. Newly matured adults may remain in the seeds for some time before they emerge. Shortly after emergence copulation takes place and is repeated at frequent intervals throughout life. Parthenogenetic eggs may be laid occasionally, but do not hatch.

It has been found that of adults held at 85° F. under starvation conditions 50 per cent may die by the end of the first week, with a certain few surviving for 19 days. Others, kept at 55° F., were very sluggish; 50 per cent survived for about 3 weeks, and one for 65 days. When given food, adult life is much longer and averaged between 7 and 8 months. Numerous adults lived well over 1 year and of certain adults subjected to a temperature ranging between 50° and 60° F., a few lived for 2 years and 5 months.

Adults begin ovipositing during summer as early as six days after emergence. In early spring the preoviposition period is about three weeks. Adults that emerge late in the fall have the longest preoviposition period, since they hibernate and do not begin ovipositing until the following spring. The extremes found in the preoviposition period were 6 and 148 days.

The granary weevil lays from one to five eggs per day when oviposition occurs, although one or two eggs per day is the more usual number. There is, however, considerable variation, as between different females, in the number of eggs laid per day under identical temperature conditions. This same variation extends to the duration of oviposition and to the total number of eggs laid by females. The longest oviposition period recorded was 287 days, from August 27 to June 10 of the year following. The shortest oviposition period was 67 days, from March 19 to May 25. The average length of the oviposition period for adults emerging during spring and early summer is between three and four months. The total egg-laying capacity of single females varied from 36 to 254.

The incubation period varied in length from 4 days at a mean temperature of 78° to 80° F. to 15 days at a mean of 61° F. No eggs were observed to hatch after the temperature of the grain had reached 95° F. or above, or when it had fallen to 50° to 55° F. Since adults do not oviposit until the temperature is from 61° to 63° F., and do not oviposit with regularity until a temperature of 66° to 68° F. is reached, there seems little reason to believe that eggs are ever laid when they can not hatch within 15 days, unless it be in late fall on approach of cold weather, when they will fail to hatch and will die.

The larva must have for food seeds in size sufficient to supply its growth requirements. In its growth it molts three times at more or less regular intervals. Where development proceeded fairly rapidly the duration of the four larval instars was found to be as follows when the mean temperature varied from 59° to 84° F.: First instar, 4 to 12 days; second instar, 4 to 14 days; third instar, 4 to 17 days; fourth instar, 6 to 24 days. With a good supply of normal moisture content the larvæ completed their development in from 19 to 34 days during summer weather when the mean temperature ranged from a maximum of 93° F. to a minimum of 70° F. The longest larval development recorded by the writers is 59 days when the mean temperatures varied between 77° and 49° F.

After attaining its growth the larva prepares a pupal cell, and after from one to two days in the prepupal form it transforms to the pupa. During the hottest summer weather, when the mean temperatures vary from a maximum of 85° to 95° F. to a minimum of 61° to 71° F., the pupal stage lasts from 5 to 7 days (mean temperatures for the period varying from 68° to 82° F.). During colder weather, with a mean temperature for the period of development

varying from 61.5° to 68.5° F., the pupal stage lasted from 10 to 16 days.

The developmental period from egg to adult may be completed in 28 days, which, with a preoviposition period of 7 days, makes possible a life cycle from egg to egg of 35 days. The normal egg-to-adult cycle in summer is between 30 and 40 days, to which should be added, in securing the egg-to-egg cycle, a period varying from 6 days in midsummer to 148 days if the adult happens to emerge during the fall and hibernate as adult. There may be three or four generations a year in the vicinity of Washington, D. C.

The granary weevil is very resistant to low temperatures. Practically all of a large number of adults refrigerated at 30° to 35° F. were found alive after one month, and a few survived for 73 days. Adults exposed to a constant temperature of 15° F. survived only for 9 days, to 5° F. for 7½ hours, and to zero Fahrenheit for 5 hours. Of eggs exposed to 30° F. for 28 days, 20 per cent survived. A few larvæ survived refrigeration at 30° F. for 44 days.

The granary weevil is not very resistant to high temperatures. Exposure for a few hours to 115° F. will kill all stages, and all stages are killed within one hour when exposed to 118° to 120° F. Moderately high temperatures are also fatal if maintained for any length of time. At 95° F. four-fifths of the adults died on the fifth day of exposure, and a few lived 9 days, and one for 13 days; little or no feeding occurred and no eggs were laid. Eggs incubated at 95° F. failed to hatch, and larvæ exposed to this temperature did not complete their development.

The granary weevil in both larval and pupal stages is attacked by several hymenopterous parasites. Although these may become very numerous at times, they can not be depended upon for effective control, which can be secured only by heating the grain to a temperature of 125° F. or above, or by fumigation with standard effective fumigants.

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